Epidemiology of Sporadic *Campylobacter* Infection in the United States and Declining Trend in Incidence, FoodNet 1996–1999

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***Campylobacter* species are a leading cause of foodborne illness in the United States, but few population-based data describing patterns and trends of disease are available. We summarize data on culture-confirmed cases of *Campylobacter* infection reported during 1996–1999 to the Foodborne Diseases Active Surveillance Network (FoodNet) system. The average annual culture-confirmed incidence was 21.9 cases/100,000 population, with substantial site variation (from 43.8 cases/100,000 population in California to 12.2 cases/100,000 population in Georgia). The incidence among male subjects was consistently higher than that among female subjects in all age groups. The incidence trended downward over the 4 years, with incidences of 23.6, 25.2, 21.4, and 17.5 cases/100,000 population for 1996–1999, respectively—a 26% overall decrease. This trend was sharpest and most consistent in California. Overall, we estimate that ~2 million people were infected with *Campylobacter* in the United States each year during this time period. Although the number of *Campylobacter* infections appears to have decreased in the United States during 1996–1999, the disease burden remains significant, which underscores the need to better understand how the disease is transmitted.**

Campylobacter jejuni was first isolated from human diarrheal stool in 1972 by use of a filtration technique that had been developed for veterinary medicine [1]. With the development of improved culture techniques during the 1970s, *Campylobacter* was recognized as a leading cause of bacterial gastroenteritis in the United States and elsewhere. In the United States, the estimated number of persons infected each year with *Campylobacter* is 1.70–2.45 million [2–4].

Outbreak investigations have identified unpasteurized milk [5–7], undercooked poultry [8], and improperly treated surface water [2, 9, 10] as the main sources of human *Campylobacter* infection. Studies of sporadic *Campylobacter* infections in limited populations have found risk factors similar to those identified in outbreaks, as well as other risk factors, such as prior antibiotic use [11], contact with domesticated animals (e.g., puppies or kittens) [12–14], contact with farm animals [15], and foreign travel [12]. Preliminary results from a large case-control study of sporadic cases of *Campylobacter* infection conducted by the Foodborne Diseases Active Surveillance Network (FoodNet) in 1996–1997 [16] found numerous factors to be associated with increased risk, including eating poultry and nonpoultry meat in restaurants, eating raw seafood,

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international travel, contact with puppies and farm animals, and male sex. That study also found a number of different exposures to be independent protective factors, including eating poultry and nonpoultry meat at home and eating at fast-food restaurants. Another recent study in FoodNet surveillance areas found high rates of *Campylobacter* contamination of chicken at US grocery stores, which supports the findings of risk being associated with handling and eating chicken [17].

Previous descriptions of population-based data on the incidence and trends of *Campylobacter* infection in the United States are limited [2, 18]. We report data on *Campylobacter* infection based on active, population-based, laboratory surveillance conducted by FoodNet during 1996–1999 and describe in detail the patterns and trends in the demographic characteristics of patients, the seasonality of infections, specimen source, and the hospitalization rate. We also estimate the number of persons with *Campylobacter* infection in the United States.

SUBJECTS AND METHODS

FoodNet is a collaborative effort among participating state and county health departments, laboratories, the Centers for Disease Control and Prevention, the Food Safety and Inspection Service of the United States Department of Agriculture, and the US Food and Drug Administration. FoodNet conducts active laboratory-based surveillance for culture-confirmed cases of infection with *Campylobacter* and other foodborne pathogens. Although clinical laboratories did not forward *Campylobacter* isolates to state public health laboratories for species verification, it is likely that the great majority of isolates were *C. jejuni* or *Campylobacter coli* [2]. We conducted the study in accordance with guidelines for human research as specified by the US Department of Health and Human Services.

FoodNet surveillance began in 1996 in Minnesota, Oregon, and selected counties in California, Connecticut, and Georgia. The surveillance areas (also called "FoodNet sites") expanded each year, and by 1999 they included the 1996 locations and additional counties in Connecticut, Maryland, New York, and Georgia. On the basis of 1999 postcensus estimates by the US Bureau of the Census, the population of the original 5 FoodNet sites was 14,782,206 (5.4% of the US population), and that of the entire FoodNet area was 25,859,311 (9.5% of the US population). We used the 1996, 1997, 1998, and 1999 postcensus estimates to calculate incidence for each of these years, which were expressed per 100,000 population. Because of our interest in incidence patterns over time, we restricted most analyses of demographic variables to the original FoodNet sites, so that data from the areas added did not influence any observed trends. However, we also included data for the expanded 1999 FoodNet sites, because of the importance of describing the overall patterns from this much larger population and because of the unique features of some of the added sites. Most of our analysis is descriptive and includes the incidence of *Campylobacter* infection by state or site; the sex, age group, and race/ethnicity of patients; and the month and year of collection of the diagnostic specimen. Because of the particularly high incidence of *Campylobacter* infection in California, we conducted additional analyses for the 2 counties in the California FoodNet site, Alameda and San Francisco; their 1999 postcensus populations were 1,415,582 and 746,777, respectively. Our analysis of bacteremia and hospitalization was based on data from all years and all sites combined. To determine the likelihood of hospitalization, we used multivariable logistic regression, with a model that included site, the age group, race/ethnicity, and sex of patients, and the source of the diagnostic specimen.

For the race/ethnicity variable in the present article, subjects were coded on the basis of their race, except for those whose ethnicity was reported as Hispanic, who, regardless of race, were coded as Hispanic. To adjust incidence and case counts in the race/ethnicity categories for missing data, we assumed that, each year, in each FoodNet site, the race/ethnicity distribution of subjects whose race/ethnicity data were missing was identical to the race/ethnicity distribution of those whose data were present. To analyze the percentage of case patients who were hospitalized and the percentage of those with bacteremia, we used standard χ^2 and logistic regression methods using SAS software, version 6.12 (SAS Institute). Because San Francisco had a high incidence of *Campylobacter* infection and a high prevalence of AIDS, we collaborated with the San Francisco Department of Public Health AIDS Office to merge the San Francisco FoodNet data with the San Francisco AIDS registry, to determine the proportion of subjects with *Campylobacter* infection who were reported to have AIDS through 2000.

To estimate the burden of *Campylobacter* infection in the United States by year, we used, with slight modification, the method of Vose et al. [4]. The method and our modifications are summarized in table A1 in the Appendix. Data inputs for the model that differ from those of Vose et al. are shown in table A2 in the Appendix. This method used data from the FoodNet population survey to estimate the proportions of the population with bloody and nonbloody diarrhea, the proportions of these who sought medical care, and the proportions among those who sought medical care who provided a stool specimen for testing. Data from the FoodNet laboratory survey on the proportion of clinical laboratories in the FoodNet sites that routinely test for *Campylobacter* were also used. These data were combined with the observed incidence of invasive and noninvasive *Campylobacter* infection reported in each FoodNet site, the proportion of the US population represented by the FoodNet sites, and other parameters described in Appendix and in Vose et al. [4]. For each parameter in the model, a

statistical distribution (e.g., gamma and beta) was used to describe the uncertainty in the estimate. A simulation procedure was used to calculate final estimates and uncertainty intervals.

RESULTS

During 1996–1999, there were 12,707 cases of culture-confirmed *Campylobacter* infection ascertained in the 5 original FoodNet sites. *Campylobacter* was the most commonly detected enteric bacterial pathogen in the original FoodNet sites each year, with an average annual incidence of culture-confirmed cases of 21.9 cases/100,000 persons. The average annual incidence in the 5 original sites ranged from 12.2 cases/100,000 persons in Georgia to 43.8 cases/100,000 persons in California (table 1). The 2 counties in the California site, San Francisco and Alameda, had particularly high average annual incidences (63.9 and 33.1 cases/100,000 persons, respectively.) There was a downward trend in the number of culture-confirmed cases over the 4 years at the original sites, with 3367 cases reported in 1996, 3628 reported in 1997, 3127 reported in 1998, and 2585 reported in 1999, which corresponds to incidences of 23.6, 25.2, 21.4, and 17.5 cases/100,000 persons, respectively. This was an overall 26% decrease in incidence from 1996 to 1999, but this decrease was not uniform across all sites (figure 1). The incidence of culture-confirmed *Campylobacter* infection at the California site decreased each year, with a 44% decline from 1996 to 1999. The incidence at the other 4 original sites increased from 1996 to 1997 and then declined from 1997 to 1999, with overall declines from 1996 to 1999 ranging from 11.6% in Connecticut to 19% in Georgia.

Table 1. Incidence and number of culture-confirmed cases of *Campylobacter* infection, by year and demographic factor, for original FoodNet sites (1996–1999) and all sites (1999).

	Data for original sites										Data for all sites, 1999[a]	
	Annual incidence, cases per 100,000 population					Percentage decrease in incidence, 1996–1999	No. of cases per year				Incidence, cases per 100,000 population	No. of cases
Variable	1996	1997	1998	1999	Average, 1996–1999		1996	1997	1998	1999		
Overall	23.6	25.2	21.4	17.5	21.9	25.8	3367	3628	3127	2585	14.8	3832
Site												
California	57.6	48.8	36.8	32.2	43.8	44.1	1189	1026	789	697	32.2	697
Connecticut	16.2	18.9	17.0	14.3	16.6	11.6	263	306	276	232	17.2	564
Georgia	12.0	14.1	12.9	9.7	12.2	18.9	328	392	367	283	8.6	673
Maryland	…	…	…	…	…	…	…	…	…	…	6.8	166
Minnesota	19.1	25.0	21.2	16.4	20.4	14.4	891	1171	1002	782	16.4	782
New York	…	…	…	…	…	…	…	…	…	…	17.2	359
Oregon	21.7	22.6	21.1	17.8	20.8	18.0	696	733	693	591	17.8	591
Sex												
Female	21.6	22.1	18.5	15.2	19.4	29.5	1572	1619	1377	1147	13.1	1726
Male	25.4	28.2	24.3	19.7	24.4	22.6	1783	1999	1746	1427	16.6	2102
Age in years												
<1	69.2	57.9	52.2	45.4	56.2	34.4	134	113	103	91	40.0	142
1–4	42.0	49.2	40.1	33.6	41.2	20.0	331	386	316	267	28.6	404
5–9	18.7	18.6	14.6	12.7	16.2	32.0	189	190	150	131	10.7	199
10–14	12.0	11.2	9.5	7.3	10.0	39.2	121	113	98	77	7.1	132
15–19	19.6	16.6	14.4	13.6	16.0	30.9	192	167	149	143	11.3	208
20–29	34.3	32.8	29.9	24.0	30.3	30.0	676	646	591	476	19.3	657
30–39	24.9	29.9	23.8	20.5	24.8	17.6	627	743	588	498	17.2	727
40–49	21.9	23.4	20.0	16.3	20.4	25.5	492	532	465	388	14.1	572
50–59	17.7	23.8	20.2	15.8	19.4	10.7	238	342	306	250	12.7	357
⩾60	16.3	17.5	15.9	11.3	15.3	30.3	363	393	360	259	9.9	403
Race/ethnicity[b]												
White	22.0	24.8	21.4	17.2	21.4	22.0	2438	2758	2395	1927	15.3	2980
Black	16.8	15.0	10.2	9.9	13.0	41.4	245	223	156	155	6.9	268
Hispanic	35.0	34.3	26.0	30.9	31.6	11.9	293	305	240	300	27.0	359
Asian	41.8	37.8	34.1	20.1	33.5	51.8	334	312	297	181	17.9	196

[a] Includes additional counties in original sites and additional sites.
[b] Adjusted for missing data.

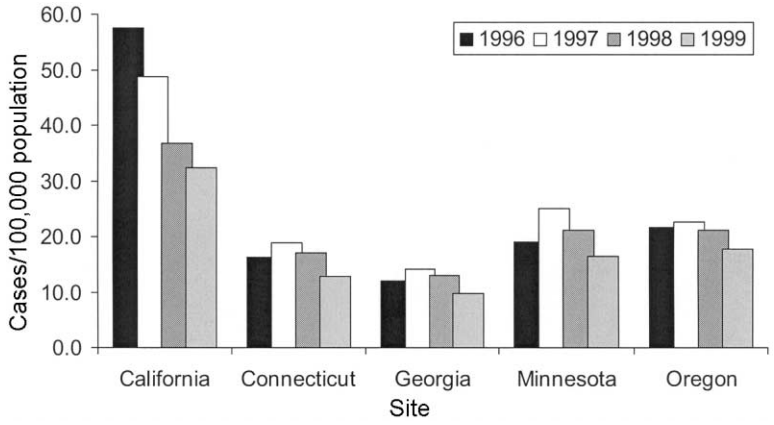

Figure 1. Incidence of culture-confirmed cases of *Campylobacter* infection, by site and year, in the original FoodNet sites, 1996–1999

Including all new sites and the expanded original FoodNet sites, 3832 cases (incidence, 14.8 cases/100,000 population) were reported in 1999. The incidence in the expanded FoodNet sites in 1999 varied from 32.2 cases/100,000 population in California to 6.8 cases/100,000 population in Maryland.

The average annual incidence of *Campylobacter* infection varied by sex and age. Male subjects had a higher incidence of *Campylobacter* infection each year; the overall 4-year average annual incidence was 24.4 cases/100,000 male subjects and 19.4 cases/100,000 female subjects (table 1). A bimodal pattern was seen in the incidence of *Campylobacter* infection by age group. The average annual incidence was highest at the original sites among infants aged <1 year (56.2 cases/100,000 population) and children aged 1–4 years (41.2 cases/100,000 population), was next highest among persons aged 20–29 years (30.3 cases/100,000 population), and decreased again among the group aged ⩾60 years (15.3 cases/100,000 population) (table 1). This distinct bimodal pattern was seen for both male and female subjects in both California counties and in the rest of the FoodNet sites (figure 2). This pattern was observed in most sites, except for a relative excess in incidence in San Francisco in persons aged 30–49 years. In almost all age groups, in all regions, the incidence of *Campylobacter* infection was higher among male than among female subjects.

For 1996–1999, race/ethnicity data were only available for 57% of the patients with culture-confirmed cases in the original sites. After adjustment for missing data, the overall average annual incidence during 1996–1999 among Asians (33.5 cases/100,000 population) and Hispanics (31.6 cases/100,000 population) was higher than that among non-Hispanic whites (21.4

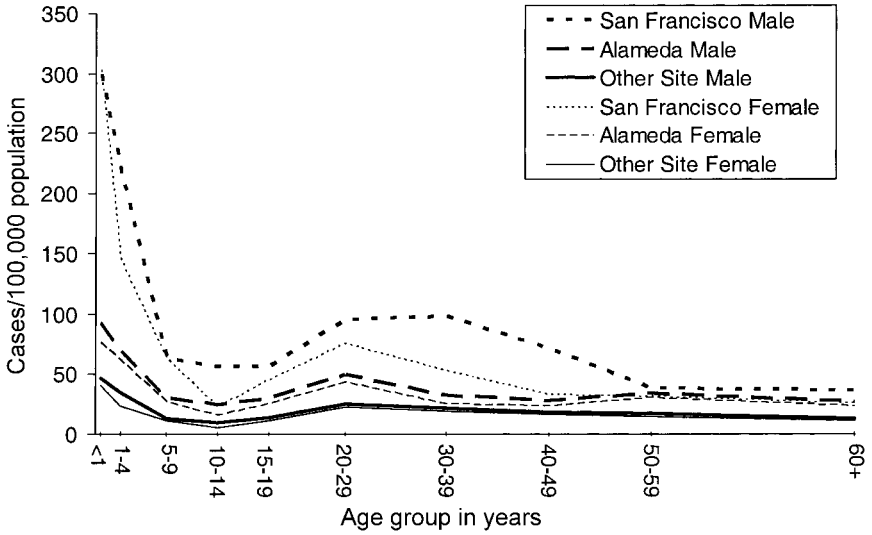

Figure 2. Incidence of culture-confirmed cases of *Campylobacter* infection, by age and sex, for San Francisco and Alameda counties, California, and for other original FoodNet sites, 1996–1999.

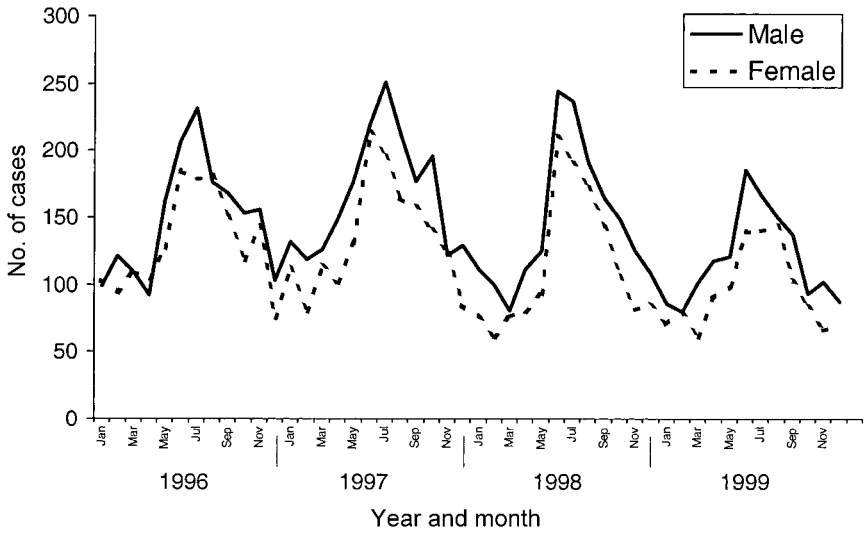

Figure 3. Number of culture-confirmed *Campylobacter* infections, by month of occurrence and sex of the case-patient, in the original FoodNet sites, 1996–1999.

cases/100,000 population), and the incidence among blacks was lower (13.0 cases/100,000 population). The only consistent pattern of incidence by race/ethnicity at each of the original sites was that the incidence was lower among blacks.

A strong seasonal pattern was seen with cases of *Campylobacter* infection each year, with numbers of *Campylobacter* infection increasing at all sites during the spring and peaking in June or July. The pattern was similar for male and female subjects (figure 3) and in all FoodNet sites.

Of the 15,181 *Campylobacter* isolates reported during 1996–1999 from all FoodNet sites, 99% (14,971) were from stool or rectal swab specimens, 1% (149) were from blood, and 0.4% (61) were from other or unknown sources. The proportion of *Campylobacter* isolates that were from blood was higher in Maryland (4%) than in any other state (range, 0.3%–1.4%). By age, the proportion of isolates from blood was highest among persons aged ⩾60 years (2%); by race/ethnicity, it was highest among blacks (3%) and was lowest among non-Hispanic whites (0.9%). A particularly high proportion of isolates from blood was seen among blacks in Maryland (7%) and Georgia (4%).

Again using data for 1996–1999 from all sites, 1481 (10%) of the 14,070 case patients for whom data were available were hospitalized. The proportion of patients hospitalized varied from 8% in California to 15% in Georgia (table 2). The highest hospitalization rates occurred among persons aged ⩾60 years (27%) and among blacks (21%). Fifty-six percent of persons with *Campylobacter* isolated from their blood were hospitalized. In the multivariate model (which controlled for race/ethnicity, state, specimen source, age, and sex), persons in Connecticut and Georgia were more likely (OR, 1.9) to be hospitalized than were those in California; those with *Campylobacter* isolated from blood were much more likely to be hospitalized (OR, 10.2) than those with *Campylobacter* isolated from stool or rectal swab specimens; and those aged ⩾60 years were more likely to be hospitalized (OR, 3.5) than persons aged 10–49 years. Overall, those who were hospitalized had a mean length of stay of 4.6 days, and 8% were hospitalized for >1 week. Two extreme lengths of stay were 137 days, for an infant hospitalized at birth, and 76 days, for an adult who developed Guillain-Barré syndrome. Four persons with *Campylobacter* infection died in 1996, 1 died in 1997, 2 died in 1998, and 4 died in 1999.

Of 1878 persons with *Campylobacter* infection during 1996–1999 in San Francisco, 135 (7%) had AIDS, according to the San Francisco Department of Health. Most (95%) of these were men aged ⩾20 years. Of the men in this age group who had *Campylobacter* isolated from stool, 15% (118 of 807) had AIDS; of men with blood isolates, 50% (10 of 20) had AIDS. If these San Francisco men with AIDS are excluded from incidence calculations, the relative excess of infections among men aged 30–39 years in San Francisco in figure 2 is eliminated.

On the basis of 1999 surveillance data from all FoodNet sites, the estimated mean annual number of *Campylobacter* infections in the United States, according to our projection model (see Appendix), is 1.4 million (median, 1.3 million), with a 90% uncertainty interval of 0.9–2.1 million. If we use surveillance data from the original sites only and hold all other parameters constant, we estimate that 2.1 million infections occurred in 1996, that 2.3 million occurred in 1997, that 2.0 million occurred in 1998, and that 1.6 million occurred in 1999. These projections yield an average overall multiplier of 34 for the

Table 2. Hospitalization rate for patients with culture-confirmed *Campylobacter* infection in all FoodNet sites, 1996–1999.

Site or characteristic	Percentage of patients hospitalized	Multivariate model results[a]	
		OR	*P*
Site			
California	7.9	Reference	…
Connecticut	12.2	1.9	<.001
Georgia	15.2	1.9	<.001
Maryland	13.2	1.3	.2
Minnesota	11.4	1.7	<.001
New York	11.4	1.1	.5
Oregon	8.1	1.0	.9
Age group, years			
<1	10.8	1.1	.6
1–9	5.5	0.5	<.001
10–49	8.7	Reference	…
50–59	11.2	1.4	.002
⩾60	26.8	3.5	<.001
Race/ethnicity			
White	13.3	Reference	…
Black	20.7	1.9	<.001
Hispanic	11.9	1.3	.05
Asian	9.4	1.1	.7
Sex			
Male	9.8	Reference	…
Female	11.5	1.3	<.001
Specimen source			
Stool	10.1	Reference	…
Blood	56.1	10.2	<.001

[a] Controlling for the variables shown.

estimated true number of *Campylobacter* infections that occurred for each reported culture-confirmed case.

DISCUSSION

Active laboratory-based surveillance data from FoodNet indicated that *Campylobacter* is a leading cause of bacterial gastroenteritis in the United States, with an average annual incidence of ~21 culture-confirmed cases/100,000 population during 1996–1999. The actual burden of illness is much greater, however; ~1.4–2.3 million persons become infected nationwide each year, which correponds to an annual incidence of ~500–850 infections/100,000 persons.

During 1996–1999, the incidence of reported culture-confirmed *Campylobacter* infection in the 5 original sites decreased 26%, from 23.6 to 17.5 cases/100,000 population. The decrease was most pronounced (44%) in California. This decline is particularly noteworthy, because many other industrialized nations are experiencing an increase in the reported incidence of *Campylobacter* infection [19]. There is no clear single explanation for why this decrease occurred. The decrease occurred at the same time as increased disease-prevention efforts in the poultry industry, such as increases in the volume of water used in processing and more attention paid to the disinfection of processing water. The decrease also occurred during the time the Pathogen Reduction (PR)/Hazard Analysis and Critical Control Points (HACCP) systems final rule was implemented in meat and poultry slaughter and processing plants [20]. Industries operating under the PR/HACCP regulations have increased the use of several important control measures, such as the use of trisodium phosphate as a decontaminant in poultry rinse water. The PR/HACCP regulations were implemented in 1997 in large processing plants and subsequently in smaller facilities. Some of the observed decrease in the incidence of *Campylobacter* infection could also be due to efforts to educate the population and food-service workers in basic food safety. We are not aware of changes in physician or laboratory culture practices or in patient care-seeking behavior that would explain this decrease.

It is not clear why California had a higher incidence of *Campylobacter* infection than the other sites or why the decrease in incidence was more pronounced in California. The 2 counties that constitute the California FoodNet area—San Francisco and Alameda—are both large, predominantly urban counties, with a diverse racial/ethnic mix. A wide range of unique ethnic/cultural food is available both at restaurants and markets in these counties. Conceivably, the food consumption and preparation patterns particular to the California population, both at home and in restaurants, may have contributed to the elevated incidence in *Campylobacter* infection. Results of the FoodNet population survey showed that, although persons in California were not more likely to eat foods associated with *Campylobacter* infection than were those in other FoodNet sites, they did, as a group, report eating at sit-down restaurants more frequently [21]. A partial explanation for the elevated incidence of *Campylobacter* infection in California might be a higher prevalence of HIV/AIDS. Although we found that only 7% of the San Francisco County residents with *Campylobacter* infections had received a diagnosis of AIDS according to the AIDS registry, laboratory-confirmed *Campylobacter* infections have been reported to be more common among persons with AIDS than among the general population [22]. The use of HAART among persons with HIV/AIDS during the mid-1990s might account for some of the decline seen in campylobacteriosis in California.

Another factor that possibly contributed to the higher incidence of *Campylobacter* infection in California are regulations introduced in that state during the mid-1990s concerning the marketing of poultry, which prohibited the use of subzero transport temperatures for poultry sold as fresh [23]. This mea-

sure may have reduced the frequency of the partial freezing of poultry. Because partial freezing reduces *Campylobacter* counts in poultry, contamination levels of poultry in grocery stores in California may have increased during the mid-1990s; unfortunately, no longitudinal microbiological sampling data for poultry at retail sites is available. Because these regulations were implemented nationwide during the late 1990s, it is important that more information be gathered to determine the effect of this policy banning freezing.

The strong seasonal pattern in the number of cases of *Campylobacter* infection seen in these FoodNet data, with a sharp increase starting around May and a peak in June or July, has been reported elsewhere [2, 9]. The seasonal pattern of sporadic cases differs from that of outbreak-associated cases, which is bimodal, with peaks in May and October and a nadir during the summer [2]. The rise in the number of cases during the summer may be due to higher levels of poultry contamination in warmer weather and/or to summer food-consumption patterns, including barbecuing and eating outdoors, which may result in food that is undercooked and/or cross-contaminated. In the United States, summer is a traditional time to take vacations, and this may result in increased international travel and more eating outside the home, both of which are risk factors for *Campylobacter* infection [18].

Although age- and sex-related patterns of incidence have been reported previously [2, 9], our findings are interesting and may yield information that is useful for prevention. Incidence by age shows a strong bimodal distribution, with the highest incidence among children aged <4 years and the second highest among persons aged 20–29 years. The incidence is higher among male than female subjects in all age groups, including the youngest age groups, well before the effect of any likely differences in exposure. Remarkably, this sex-related difference in incidence held true at all FoodNet sites and in almost all age groups at each site. Although similar age- and sex-related patterns have been reported, the sex-related difference in those studies did not persist into the oldest age groups. Some of the sex-related difference may be explained by sex-specific differences in food-handling practices [24]. Men report more unsafe food-handling, preparation, and consumption practices than do women [25–27], and the results of the FoodNet population survey suggested that men eat more foods known to be risky for foodborne diseases than do women, including food that may be risky for *Campylobacter* contamination [28]. However, the sex-related difference in incidence persisted even among young children, which suggests that other factors may play a role. Boys aged <10 years, including infants, have a higher reported incidence of several infectious diseases, including *Salmonella* and *Shigella* infections, and it has been speculated that these differences may be due to greater susceptibility to infectious diseases among males [29].

The correlation between hospitalization rates and age among persons with *Campylobacter* infection is not surprising, given the decreased immune function of elderly persons and, possibly, a greater propensity for clinicians to hospitalize elderly persons as a precautionary measure. The higher hospitalization rates in some states and among blacks are not fully understood. A plausible explanation for the higher hospitalization rates among blacks is that blacks may be less likely to be seen by a physician for mild *Campylobacter* infection (a possibility supported by their lower rates of reported *Campylobacter* infection overall), so that only cases that are more severe, and thus more likely to be hospitalized, are seen.

Although FoodNet provides high-quality population-based data on the incidence, patterns, and trends of foodborne diseases in the United States, the data have several limitations. First, the original FoodNet sites represented only 5.4% of the US population (and the 1999 FoodNet sites only 9.5%). Even though the FoodNet sites are spread throughout the country, they are not a random sample of US counties or states and may differ from the rest of the country. In some states, participating counties may not be representative of the state as a whole. For these reasons, FoodNet data cannot be extrapolated to the entire United States without caution. There are also limitations in the data that are collected, including limited data on race and ethnicity and incomplete data on survival rates. Furthermore, some cases are missed altogether, because laboratories outside the FoodNet sites do not always report results to the local jurisdiction, and, if they are reported, local jurisdiction may not always report these cases to the state.

Our estimates indicate that ~1.5 million people were infected with *Campylobacter* in the United States in 1999 and that ~2 million were infected each year during 1996–1998. These estimates are consistent with those of previous reports and illustrate the enormous burden of *Campylobacter* infection in the United States. The method that we used to make these estimates included many individual parameters and assumptions; the uncertainty affecting the point estimates is reflected in the large uncertainty intervals. A number of parameters, such as the probability that a stool specimen for culture will be obtained from a person with bloody enteric campylobacteriosis, cannot be estimated accurately from existing data, which highlights the need for additional studies to provide data for use with this type of projection method. The changes in the FoodNet sites also had a significant influence on the estimated number of cases. We estimated that ~1.4 million cases occurred in 1999 among all FoodNet sites, which is ~200,000 cases fewer than the 1.6 million cases estimated using data from the original FoodNet sites. This lower estimate was, in large part, caused by the addition of Maryland, which has a particularly low incidence of reported *Campylobacter* infection. For comparison, we also estimated the number of *Campylobacter* infections using

the method of Mead et al. [3], in which we multiplied the number of culture-confirmed cases by 38 to estimate the total number of cases in the FoodNet sites and then extrapolated this number to the entire United States. This multiplier of 38 is based on models for *Salmonella* infection [30, 31] and is similar to but simpler than the model of Vose et al. [4] used in the present analysis (which yielded a multiplier of 34). The method of Mead et al. [3] yielded an estimate of 1.6 million cases in the United States in 1999 on the basis of data from all FoodNet sites and 1.8 million cases on the basis of data from the original FoodNet sites.

Campylobacter has been the most commonly detected enteric bacterial pathogen in the general US population. There was a decline in the reported incidence of *Campylobacter* infection during 1996–1999, when there were changes in meat-processing regulations, as well as other food safety efforts. It is difficult to allocate the decline across these efforts. The burden of acute disease caused by *Campylobacter* is important and underscores the need to better understand disease transmission in order to develop better prevention and control measures.

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APPENDIX

Table A1. Description of *Campylobacter* infection projection model parameters and estimated values.γ

Estimation sought, classification, description	Symbol	Source or formula	Value or mean of estimate from specific model run, 1999, all sites[a]
1. Nominal mean no. of culture-confirmed cases of *Campylobacter* infection reportable to health department			
Population			
Total US	n_{US}	Data	272,690,813 cases
Total FoodNet surveillance	n_{FN}	Data	25,859,311 cases
Expected observed no. of cases in FoodNet sites {j}			
Enteric	o_{ej}	Data	See table A2[b]
Invasive	o_{Ij}	Data	See table A2[b]
Expected observed no. of cases in the United States			
Enteric	λ_e	$(n_{US}/n_{FN}\Sigma_j)$ gamma$(o_{ej},1)$	(10.55) 50.97 cases
Invasive	λ_I	$(n_{US}/n_{FN}\Sigma_j)$ gamma$(o_{Ij},1)$	(10.55) 3833.04 cases
Proportion of culture-confirmed enteric cases with bloody diarrhea	p_b	Beta distribution, based on data shown in table A2[b]	0.442
Nominal mean no. of culture-confirmed cases reportable to health department			
Nonbloody	$\lambda 1_n$	$\lambda_e(1 - p_b)$	22,534.70 cases
Bloody	$\lambda 1_b$	$\lambda_e(p_b)$	17,885.33 cases
Invasive	$\lambda 1_I$	λ_I	537.51 cases
Total	$\lambda 1_T$	$\lambda 1_n + \lambda 1_b + \lambda 1_I$	40,957.54 cases
2. Nominal mean no. of cases of *Campylobacter* infection in the US			
Probability a person with campylobacteriosis seeks care			
Nonbloody cases	p_{mn}	Beta distribution on data	0.206
Bloody enteric cases	p_{mb}	Beta distribution on data	0.342
Probability a person with campylobacteriosis who has sought care is then requested to supply a stool sample, and complies			
Nonbloody cases	p_{cn}	Composite distribution on data	0.156
Bloody enteric cases	p_{cb}	Composite distribution on data	0.304
Probability a laboratory tests a stool sample for *Campylobacter*	p_t	Beta distribution on data	0.945
Probability a stool sample with *Campylobacter* tests positive by culture	p_+	Beta distribution on data	0.750
Nominal mean no. of cases of *Campylobacter* infection in US			
Nonbloody	$\lambda 2_n$	$\lambda 1_n/(p_{mn}p_{cn}p_tp_+)$	1,062,921 cases
Bloody	$\lambda 2_b$	$\lambda 1_b/(p_{mb}p_{cb}p_tp_+)$	342,064 cases
Invasive	$\lambda 2_I$	$\lambda 1_I$	538 cases
Total	$\lambda 2_T$	$\lambda 2_n + \lambda 2_b + \lambda 2_I$	1,405,522 cases

NOTE. Model based on that of Vose et al. [4].

[a] Based on the same input data as those of Vose et al. [4], except where noted.

[b] Input data differ from those of Vose et al. [4].

Table A2. Input values for projection-model parameter estimation for those parameter values differing from the original model.

	No. (%) of infections			
	From 1999 FoodNet surveillance data		From FoodNet *Campylobacter* case-control study[a]	
State	Enteric	Invasive	Total	With bloody diarrhea
California	685	12	307	130 (42.3)
Connecticut	552	12	395	149 (37.7)
Georgia	654	5	288	133 (46.2)
Maryland	152	10	167	82 (49.1)
Minnesota	775	3	316	143 (45.3)
New York	351	2	156	70 (44.9)
Oregon	583	5	278	123 (44.2)
Total	3750	49	1907	830 (43.5)

[a] Unpublished FoodNet data.

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